



## Outsourcing of Production

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*Published in:*  
LogForum

*DOI (link to publication from Publisher):*  
[10.17270/J.LOG.2018.263](https://doi.org/10.17270/J.LOG.2018.263)

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*Publication date:*  
2018

*Document Version*  
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*  
Asmussen, J. N., Kristensen, J., & Wæhrens, B. V. (2018). Outsourcing of Production: The Valuation of Volume Flexibility in Decision-Making. *LogForum*, 14(1), 73-83. [7]. <https://doi.org/10.17270/J.LOG.2018.263>

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## OUTSOURCING OF PRODUCTION: THE VALUATION OF VOLUME FLEXIBILITY IN DECISION-MAKING

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**ABSTRACT. Background:** Outsourcing remains a central mechanism for improving manufacturing supply chains, with volume flexibility being a frequently targeted objective. However, outsourcing decision-making remains focused on static cost estimations, while the value of volume flexibility is subject to managerial valuation, thus imposing a risk of estimation errors. This paper tests whether decision-makers systematically under- or overvalue volume flexibility when deciding on outsourcing.

**Methods:** Four outsourcing decisions made by an OEM operating with seasonality and boom and bust cycles are analyzed to assess if decision-makers' intrinsic valuation of volume flexibility is biased. This was done by utilizing a previously developed mixed integer linear programming model for tactical planning. The model jointly considers production planning, workforce adjustments and capital investment, while respecting upstream supplier constraints, thereby encompassing both positive and negative effects of production outsourcing on volume flexibility. Combining the model with detailed knowledge of how the production system would be impacted, enabled a quantification of the value from volume flexibility, which could then be compared to the decisions made.

**Results:** Augmenting existing static cost estimations with the value of flexibility did not reveal systematic estimation errors. However, the results suggest that the value of volume flexibility is situational, and on average comparable to direct labor cost.

**Conclusions:** The results emphasize the importance of accurately and case-specific valuation of volume flexibility in cost-driven production outsourcing.

**Key words:** volume flexibility, production outsourcing, decision-making.

## INTRODUCTION

Outsourcing remains a principal mechanism for improving manufacturing supply chains. Extant literature covers numerous benefits associated with outsourcing, such as cost reduction, focus on core competencies, access to suppliers with economies of scale and specialized process knowledge, and the ability to leverage existing capital investments and expensive technology [Chang, Kuo, Chen, 2008]. Further, outsourcing is an enabler for elevating capacity shortages and increasing flexibility [Chang, Kuo, Chen, 2008], coupled with the transfer of uncertainty in demand to external contractors [Abraham, Taylor, 1996].

In this way, the use of one or more outsourcing contractors provides the focal company with the possibility to adjust the scale of production activities more rapidly, i.e. higher volume flexibility. Empirical research identified volume flexibility as a key driver for outsourcing [Scherrer-Rathje, Deflorin, Anand, 2014]. However, it is argued that the role of flexibility is insufficiently explained in the relationship between capacity planning and outsourcing [Wang, Chen, Wang, Su, 2010].

While existing literature associates production outsourcing with both loss and gains of volume flexibility [Scherrer-Rathje, Deflorin, Anand, 2014; Jack, Raturi, 2003; Jack, Raturi, 2002], the literature provides

limited guidance for decision-makers who needs to balance volume flexibility against other strategic goals, such as lowest cost, in complex decision-making situations. Consequently, when deciding whether to outsource, decision makers have been shown to rely on static cost comparisons [Gylling, Heikkilä, Jussila, Saarinen, 2015; Kumar, Kopitzke, 2008; Ferreira Prokopets, 2009], while the impact on flexibility remains qualitative. Imposing a risk of decision-makers either over- or undervaluing flexibility. Related experimental evidence does indeed reveal that decision-makers systematically overvalued flexibility derived from product substitution [Bansal, Moritz, 2015].

Improving the understanding of biases for decision-making on production outsourcing remains important. Especially as making accurate estimations of the expected outcome of outsourcing remains challenging, and subject to estimation errors [Larsen, Manning, Pedersen, 2013], with erroneous managerial valuation as a key reason for reverting decisions and back-sourcing [Gray, Skowronski, Esenduran, Rungtusanatham, 2013].

Therefore, the objective of this study is to introduce an approach enabling managers to assess the impact of volume flexibility from outsourcing, and based on the approach, test whether decision-makers systematically under- or overvalue volume flexibility when making outsourcing decisions

The paper is structured as follows: Section 2 reviews extant literature. Section 3 describes the research design and methodology. Section 4 presents the results of valuating volume flexibility. Finally, Section 5 discusses the results and managerial implications before Section 6 provides concluding remarks.

## POSITION IN LITERATURE

### Volume flexibility

Flexibility can be defined as “the ability to change or react with little penalty in time, effort, cost or performance” [Upton 1994]. It is

generally established that manufacturing flexibility is linked to performance advantages [Ward, Bickford, Leong, 1996] especially in dynamic and volatile environments. Flexibility is both a multidimensional [Sethi, Sethi, 1990] and a hierarchical construct, with plant-level flexibility supported by shop floor level flexibility [Koste Malhotra, 1999]. At the plant level, flexibility can be categorized into product, mix and volume flexibility [Slack, 1983]. Tactical flexibilities all dealing with adjusting output to match volatility in demand [Scherrer-Rathje, Deflorin, Anand, 2014]

This paper focuses on one specific aspect of flexibility, volume flexibility. Volume flexibility denotes the ability of a manufacturing system to be “operated profitably at different overall output levels” [Sethi, Sethi, 1990]. Similarly [Jack, Raturi, 2003] defines volume flexibility as “the ability of a firm to sustain high output fluctuations without high transition penalties”. Volume flexibility can thus be perceived as the steepness of an average product cost curve on both sides of its minimum. The flatter this curve is, the higher is the volume flexibility [Goyal, Netessine, 2011]. At the tactical plant level, measures for volume flexibility reflect operational characteristics and decisions, such as level or chase workforce, inventory buffers, capacity buffers, and overtime [Jack, Raturi, 2003]. The volume flexibility resulting from these can be translated into three elements. The range of possible aggregate production volumes the system can attain. The ease of which the system can transition from one state to another, reflected by the cost incurred of adopting a new state and the time required to do so [Slack, 1983].

### Production outsourcing and volume flexibility

Outsourcing is understood as “the act of obtaining semi-finished products, finished products or services from an outside company if these activities were traditionally performed internally.” [Dolgui, Proth, 2013]. While firms outsource manufacturing activities for numerous reasons, the focus is on the impact on volume flexibility, which is a frequently targeted objective from outsourcing [Scherrer-Rathje, Deflorin, Anand, 2014].

Outsourcing of production activities influences the three elements of volume flexibility at the plant level in different ways. First, the labor content added in the production determines the workforce level required for producing a certain amount of products in a given time. Reducing labour content added by the focal company would thus reduce the overall workforce. As adjusting the workforce is associated with costs, e.g. recruitment and training costs or severance pay, it would reduce the cost of continuously adjusting the workforce to accommodate higher or lower aggregate production volumes. Reduction of the work content would additionally reduce the cost of utilizing overtime, thereby, having a dual impact on the cost dimension of volume flexibility.

Outsourcing of production is associated with utilizing suppliers' production equipment and thereby breaking internal equipment bottlenecks [Ronen, Spector, 1992]. The impact on volume flexibility from eliminating equipment bottlenecks can be seen through increasing the potential upside range of capacity without investing in additional production equipment. Further, the time for transition is impacted by outsourcing bottleneck processes, as the lead-time for acquiring additional production equipment is eliminated. As the use of overtime is normally constrained by the number of overtime hours, increasing the hourly output, beyond previous bottlenecks, would thus also increase the range of volume flexibility, as more output can be produced in the hours available for overtime production.

Translating these operational changes when outsourcing to increased volume flexibility entails, that the focal company will benefit from the "supplier's large production capacities or stock of inventory that are generally used to supply materials to many companies – including the outsourcing company" [Scherrer-Rathje, Deflorin, Anand, 2014] and pooling of demand fluctuations. However, the realization of intended volume flexibility is dependent on the power balance between the focal company and the supplier, and the extent to which production relies on highly specific assets [Scherrer-Rathje, Deflorin, Anand, 2014].

Outsourcing is also associated with potential detrimental impacts on volume flexibility. Limited flexibility in terms of committed volumes and long lead-times after outsourcing reduces volume flexibility [Scherrer-Rathje, Deflorin, Anand, 2014]. The outsourcing partners flexibility in terms of "extend to which supplier lead time can be expedited/changed[,] the extent to which supplier short-term capacity can be influenced [and the extent of] changes to delivery times of orders placed with suppliers" [Swafford, Ghosh, Murthy, 2006] thus influences the potential volume flexibility achieved by the focal company. The impact is two-fold in terms of range and cost. Material shortages due to inflexible supply conditions will reduce the possibility to increase aggregate production output. While a cost will be incurred in terms of increased inventory carrying cost of procured items, if production volumes are reduced below committed volumes.

#### **Valuation of volume flexibility in decision-making**

Empirical research provides evidence on the performance benefits of volume flexibility [Jack, Raturi 2003; Jack, Raturi, 2002]. However, in decision-making situations considering numerous trade-offs, such generic prescriptions provide limited value in balancing alternative performance criteria. The valuation of volume flexibility thus links the range, cost and time of transition, to financial measures [Walter, Sommer-Dittrich, Zimmermann 2011]. However, the complex interactions with outsourcing and volume flexibility, combined with seasonality and market uncertainty makes it difficult to determine the economic value of volume flexibility. One aspect of this challenge relates to the nature of flexibility being a capability that might not be exercised [Jack & Raturi, 2002], thus requiring decision-makers to rely on real-options thinking for valuation [Avanzi, Bicer, de Treville, Trigeorgis 2013].

Analytical research extrapolates the value of volume flexibility. For example, Goyal & Netessine [2011] addresses the value of volume flexibility in connection with product flexibility under demand correlation and different product substitution levels. However,

stylized analytical models find limited application in concrete managerial decision-making, where volume flexibility is valued against other performance objectives, in complex decisions with a large number of variables and constraints interacting [Manuj, Sahin 2011; Asmussen, Kristensen, Wæhrens 2017].

Other approaches, building on mathematical programming, values volume flexibility based on aggregate production planning models [Walter, Sommer-Dittrich, Zimmermann 2011; Khouja 1998]. Walter et al. [2011] tested five different volume flexibility measures in a design-of-experiment approach, to establish their individual and interaction effect in terms of cost. However, limitations exist in applying their model for valuating volume flexibility related to production outsourcing, as the impact on equipment bottlenecks and upstream supply chain partners are not considered.

Despite these efforts, how decision-makers value manufacturing flexibility in practice remains underexplored [Bansal, Moritz, 2015; Walter, Sommer-Dittrich, Zimmermann, 2011]. However, the extant literature indicates likely issues. The use of standard cost accounting and static net present value (NPV) calculations are inadequate when evaluating supply chains with different levels of flexibility. Suggesting that flexibility is systematically undervalued [Christopher, Holweg, 2011]. Oppositely, experiments conducted show an overestimation of the value of flexibility gained from product substitution [Bansal, Moritz, 2015].

## RESEARCH DESIGN

To investigate the managerial valuation of volume flexibility during outsourcing decisions, a two-fold research design is followed. First, together with a globally leading original equipment manufacturer (OEM), a mixed integer programming model (MILP) integrating capacity and production planning is implemented in a lean production environment [Asmussen, Steger-Jensen, Kristensen, Wæhrens, 2017]. The model considers aspects of workforce planning

(number of production workers, shift model and overtime), investment in production equipment to break internal equipment constraints, together with constraints on the inbound supply chain. Encapsulating the tactical decisions and constraints reflecting volume flexibility at the plant level, the model enables a valuation of the impact on volume flexibility from outsourcing as outlined in section 2.2. Second, four outsourcing decisions were made by the OEM. These decisions were based on a cost model addressing material, freight, duties, internal labor cost and indirect production costs, similar to cost models applied for decision-making on production outsourcing [Gylling, Heikkilä, Jussila, Saarinen 2015]. The cost estimations did not quantify the impact of volume flexibility, however, improved volume flexibility, together with total cost reductions were the drivers for initiating the outsourcing projects. In the lack of a quantified value of volume flexibility, decision-makers instead relied on their intrinsic valuation of volume flexibility, when deciding whether to outsource or maintain production activities internally. Based on the developed MILP model, it was possible to re-evaluate these decisions, to test if managerial decisions were biased in their valuation of volume flexibility.

## Case Selection

The need for volume flexibility at the OEM originates from significant demand seasonality, and frequent boom and bust cycles induced by market and industry characteristics. The OEM is thus suitable for testing the valuation of volume flexibility, as the instability of demand is established in managerial thinking and decision-making. Additionally, both executive, senior and middle-management in production and sourcing were committed to continuously evaluate the production setup, and adjust according to total cost calculations. Addressing any confounding impact of politics in decision-making [Marshall, Ambrose, McIvor, Lamming 2015]. At the plant level, producing only a single product, it was possible to eliminate the potentially confounding impact of other flexibility types, such as mix flexibility, product substitution as well as demand correlation [Goyal, Netessine 2011].



Although volume flexibility is associated with both cost efficiency and increased sales [Jack, Raturi, 2002], assessing the valuation of volume flexibility in relation to cost and not profit, is meaningful at the specific plant, as the ability to sell to customers was constrained by parallel factories in the OEM's manufacturing network. Increased volume flexibility at the selected plant would consequently not influence the ability to increase sales, only higher cost efficiency at the specific plant.

To best resemble stylized experiments [Bansal, Moritz 2015] when testing the managerial valuation of volume flexibility, embedded cases were selected with the criteria, that the objective for outsourcing should be limited to, but include both total cost reduction and increased volume flexibility. For the selected cases, the OEM should maintain a favorable power-balance against the supplier, to ensure the realization of intended volume flexibility [Scherrer-Rathje, Deflorin, Anand, 2014]. Further, the outsourcing partners should be well-known and existing suppliers to the plant, with alternative suppliers available in the market, entailing that the perceived risk of suppliers behaving opportunistically was low. Thereby reducing the importance of such considerations in decision-making and reinforcing that the outsourcing decision would be made based on the calculated direct cost impact and the intrinsic managerial valuation of volume flexibility. Four cases complying with these criteria were identified. None of these embedded cases was thus driven by strategic considerations of accessing supplier competencies or technology.

### Data collection

Data on the decision process for each case was collected through interviews with project stakeholders in procurement and manufacturing, at the start of each outsourcing project, during project maturation, as well as for final decision. Further, interviews were supplemented with observations of decision meetings, to ensure a rich understanding of managerial priorities and discussion points when deciding on configurations.

The data collection intended to (1) establish the basis used in decision-making, hereunder the cost estimations of the impact of production outsourcing, (2) validate that, decision-making was focused on total cost and volume flexibility, and not alternative objectives, and (3) collect required data for modeling the impact of production outsourcing on the production system through the MILP model.

### Data Analysis

To establish and assess the managerial valuation of volume flexibility in outsourcing decision-making, the following variables were calculated:

- $OCI_c$ : Outsourcing cost impact as the direct unit cost impact from outsourcing case  $c$  excluding the impact of volume flexibility. This would be the cost estimations available during decision-making.
- $LCO_c$ : Direct labor cost per unit in outsourcing case  $c$ .
- $COPB_d$ : Cost of plan baseline for demand scenario  $d$  based on MILP model.
- $COPA_{d,c}$ : Cost of plan for demand scenario  $d$  when MILP model parameters have been adjusted for outsourcing case(s)  $c$ .
- $VVF_{d,c}$ : Value of volume flexibility for outsourcing case  $c$  in demand scenario  $d$ .

The  $COPB_d$  for three demand scenarios (boom, mean, and bust) is established by solving the MILP model [Asmussen, Steger-Jensen, Kristensen, Wæhrens 2017]. The model was solved using OpenSolver version Version 2.8.5 (2016.11.3) running on 64-bit Windows 6.2 with VBA7 in 32-bit Excel 15.0. For each outsourcing case and demand scenario, the  $COPA_{d,c}$  was found by solving the MILP model after adjusting for changes in work content, equipment bottlenecks and supplier constraints due to the production outsourcing, as illustrated in **Błąd! Nie można odnaleźć źródła odwołania..**

The delta between  $COPB_d$  and  $COPA_{d,c}$  for each demand scenario, were thus reflecting the cost difference due to direct labor savings and

volume flexibility. The value of volume flexibility could then be calculated as  $VVF_{d,c} = COPA_{d,c} - COPB_d - LCO_c$ . The direct labor cost related to the outsourced production is subtracted, since this is already accounted for in the direct cost comparison, and not related to volume flexibility.

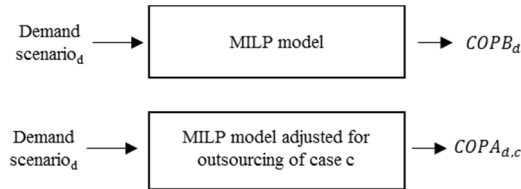


Fig. 1. Method for valuing volume flexibility

The rational decision, based on cost and volume flexibility, would then be for  $OCI_c - VVF_{d,c} > 0$  to maintain internal production

and for  $OCI_c - VVF_{d,c} < 0$  to outsource production.

## VALUATION OF VOLUME FLEXIBILITY

A two-year demand pattern reflecting seasonality is used for valuing volume flexibility. To reflect bust and boom cycles in the industry, demand scenarios of +60% and -60%, reflecting likely developments in the highly cyclical industry supplement the mean forecasted demand. The characteristics of the four outsourcing cases and the valuation of volume flexibility when solving the MILP model to near optimality is listed in Table 1. For confidentiality purposes, the numbers have been masked, however, explanatory value is maintained.

Table 1. Characteristics of outsourcing cases and value of volume flexibility

Case	#1	#2	#3	#4
Equipment bottleneck Removed	Yes	No	Yes	No
% of factory labour content	3%	1%	24%	1%
Leadtime impact	No	No	Extended	No
Outsourced	No	No	No	No
<b>OCI (+ cost increase, - cost reduction)</b>	<b>+21.5</b>	<b>+3.8</b>	<b>+109.9</b>	<b>+1.1</b>
LCO	2.8	0.8	20	0.7
COPB	165.4 -196.0			
COPA	161.3-191.6	163.6-193.4	135.9-162.7	164.3-194.9
<b>VVF</b>	<b>1.3-2.1</b>	<b>0.9-1.8</b>	<b>9.5-15.9</b>	<b>0.4-0.8</b>

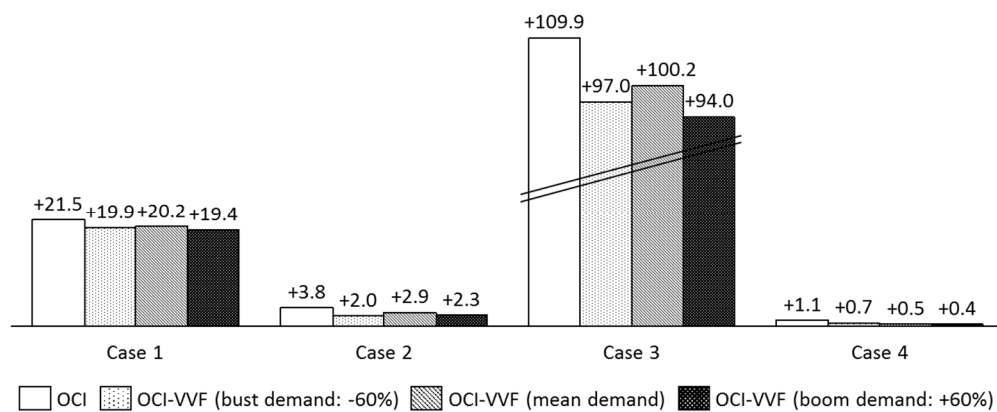


Fig. 2. Average unit cost impact from outsourcing in (+ cost increase, - Cost reduction)

The numerical results reveal that the cost difference attributed to volume flexibility ranged from 47-268% of the direct labor cost in the plant, with an average of 116%. The

result emphasize both the significance and the case specific value of volume flexibility in outsourcing decisions.

The impact of volume flexibility on average unit cost for the outsourcing cases under the different demand scenarios is depicted in Figure 2. Despite the contribution from volume flexibility and the complex interdependencies, the results do not indicate that volume flexibility have been systematically under- or overvalued in decision-making. The decisions made by the OEM to maintain production internally for all four cases does still constitute the lowest cost in all demand scenarios, thus reflect rational decision-making.

## DISCUSSION AND MANEGERIAL IMPLICATIONS

The analysis of actual high-stake decision-making does not suggest that volume flexibility is subject to systematic estimation errors, resulting in sub-optimal decision-making. However, missing evidence of suboptimal decisions could be the result of the significant gap in direct cost competitiveness exceeding any estimation errors on the valuation of volume flexibility.

Indeed, the results showing that the mean value of volume flexibility relative to labor cost is 116%, with a coefficient of variance (CoV) of 67%. The result indicate that the value of volume flexibility is comparable to internal labor cost, which normally is a key element when comparing internal production with outsourced production [Christopher, Holweg, 2011; Gylling, Heikkilä, Jussila, Saarinen, 2015]. Thus, the result highlights the relevance of explicitly considering the value of volume flexibility when making outsourcing decisions. Further, the high CoV underpins the case-specific value of volume flexibility. This indicates a significant risk of estimation errors for decision-makers relying on simple heuristics and static cost comparison. Especially, for cross-functional decision-making, dominated by departmental thought worlds [Niranjan, Rao, Sengupta, Wagner 2014], in which decision-makers do not share an intuitive understanding of the impact within other functional areas. For decisions where the cost gap between internal and outsourced production, is less significant, correctly estimating the value of volume flexibility could thus be expected to be determinant for

identifying the optimal solution. It emphasizes the necessity of considering the value of volume flexibility in the assessment of outsourcing in labor-intensive industries with aggregate demand variations. An aspect, which is normally not addressed in cost models for production outsourcing [Kumar, Kopitzke, 2008; Ferreira Prokopets, 2009].

## CONCLUDING REMARKS

The objective of this paper was to propose a method for valuating volume flexibility gained from production outsourcing, and assess if decision-makers valuation of volume flexibility is subject to systematic estimation errors. The paper utilized a MILP model [Asmussen, Steger-Jensen, Kristensen, Wæhrens, 2017] that enabled volume flexibility from production outsourcing to be valued in a lean assembly environment. Extending existing approaches for valuing volume flexibility [Walter, Sommer-Dittrich, Zimmermann, 2011] by integrating equipment bottlenecks and investment decision together with upstream supplier constraints, it was possible to capture both the positive and negative impact from production outsourcing on volume flexibility. By combining the MILP model for aggregated production planning, with a detailed understanding of real-life high-stake decision-making, it was possible to value volume flexibility and compare it to realized decisions. Contrary to previous work on managerial valuation of flexibility, relying on stylized experiments utilizing university students [Bansal, Moritz, 2015], the findings did not indicate an erroneous valuation of volume flexibility at a level where it impaired effective decisions making.

By relying on a single embedded case, there are limitations to the generalizability. Further, limitation lies in the direct production cost gap, between internal and outsourced production. Extending this study with multiple embedded cases, would thus seek to increase generalizability. While extending the number of decision situations, and ensuring an even distribution of direct cost impact on both sides of break-even, would improve the accuracy in the understanding of managerial biases when valuating volume flexibility.



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## OUTSOURCING PRODUKCJI. SZACOWANIE ELASTYCZNOŚCI W PROCESIE PODEJMOWANIE DECYZJI

**STRESZCZENIE. Wstęp:** Outsourcing pozostaje głównym mechanizmem poprawy funkcjonowania łańcucha dostaw, przy szacowaniu elastyczności jako głównym mierniku oceny. Niemniej, proces podejmowania decyzji odnośnie outsourcingu jest głównie skupiony na estymacjach kosztów statycznym, podczas gdy szacowanie elastyczności podlega ocenie wartości zarządzania, a co jest z tym związane, ryzykiem estymacji błędów. Prezentowana praca przedstawia ocenę wyceny elastyczności procesu podejmowania decyzji w sprawach dotyczących outsourcingu.

**Metody:** Poddano analizie cztery decyzji podjęte przez OEM przy występującej sezonowości, wzrostu oraz spadku w celu określenia istotności oszacowania podejmowanych decyzji z punktu widzenia elastyczności. Analizę tą wykonano przy zastosowaniu połączenia modelu zintegrowanego programowania liniowego dla planowania taktycznego. Model ten obejmuje planowanie produkcji, zarządzanie zasobami oraz inwestowania kapitałem przy uwzględnieniu ograniczeń w łańcuchu dostaw, co oznacza uwzględnianie wpływu zarówno pozytywnych jak i negatywnych efektów outsourcingu produkcji na oszacowanie elastyczności. Połączenie tego modelu z wiedzą dotyczącą prawidłowego funkcjonowania procesu produkcyjnego pozwoliło na skwantyfikowanie elastyczności. Otrzymane wyniki posłużyły do analizy porównawczej podjętych decyzji.

**Wyniki:** Zwiększanie estymacji istniejących kosztów statycznych z wartością elastyczności nie wyjaśnia błędów systematycznych estymacji. Niemniej jednak wyniki sugerują, że wartość elastyczności ilości jest zależna od sytuacji i średnio porównywalna z kosztem bezpośrednim robocizny.

**Wnioski:** Otrzymane wyniki wskazują na istotność dokładnej i precyzyjnej wyceny wartościowej elastyczności ilości w outsourcingowej produkcji w ujęciu kosztowym.

**Słowa kluczowe:** elastyczność ilości, outsourcing produkcji, proces podejmowania decyzji

## OUTSOURCING IN DER PRODUKTION. DIE EINSCHÄTZUNG VON FLEXIBILITÄT IM PROZESS DES ENTSCHEIDUNGSTREFFENS

**ZUSAMMENFASSUNG. Einleitung:** Das Outsourcing-Verfahren bleibt ein grundlegender Mechanismus zur Verbesserung der Funktionsausübung von Lieferketten angesichts der Einschätzung deren Flexibilität als eines grundsätzlichen Messwertes dieser Einschätzung. Allerdings konzentriert sich der Prozess des Entscheidungstreffens bezüglich des Outsourcing-Verfahrens hauptsächlich auf die Schätzung von statistischen Kosten, während die Einschätzung der Flexibilität einer Bemessung von Management-Werten unterliegt, was mit dem Risiko der Ästimation von Fehlern verbunden ist. Die vorliegende Arbeit projiziert die Auswertung der Einschätzung der Flexibilität des Entscheidungstreffens innerhalb des Outsourcing-Verfahrens.

**Methoden:** Es wurden vier durch OEM getroffene Entscheidung angesichts der auftretenden Saisonabhängigkeit und der Anstiegs- und Abstiegsscheinungen zwecks der Bestimmung der Relevanz der Auswertung der getroffenen Entscheidungen aus dem Gesichtspunkt der Flexibilität einer Analyse unterzogen. Diese Analyse wurde bei Anwendung der Verbindung des Modells für die lineare Programmierung zur taktischen Verplanung durchgeführt. Da betreffende Modell umfasst die Produktionsplanung, das Ressourcen-Management und das Investieren des Kapitals bei Berücksichtigung von Einschränkungen innerhalb der Lieferkette, was die Berücksichtigung der Beeinflussung der sowohl positiven, als auch der negativen Effekte des Produktion-Outsourcings der Flexibilität-Einschätzung bedeutet. Die Anbindung des Modells an das die richtige Funktionsausübung des Produktionsprozesses anbetreffende Wissen erlaubte eine Quantifizierung der Flexibilität. Die erzielten Ergebnisse dienten der vergleichenden Analyse der getroffenen Entscheidungen.

**Ergebnisse:** Die Vergrößerung der Ästimation innerhalb der bestehenden, statistischen Kosten mit dem Flexibilitätswert klärt die Fehler von systematischen Ästimationen nicht auf. Dennoch deuten die Ergebnisse an, das der Flexibilitätswert der Menge von der Situation abhängt und durchschnittlich mit den direkten Arbeitskosten vergleichbar ist.

**Fazit:** Die erzielten Ergebnisse weisen auf die Relevanz einer genauen und präzisen Auswertung der Mengenflexibilität im Produktion-Outsourcing angesichts der Kostenannahme hin.

**Codewörter:** Mengenflexibilität, Produktion-Outsourcing, Prozess des Entscheidungs-treffens

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